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PERFORMANCE OF TALL BUILDINGS UNDER LATERAL LOADS WITH DIFFERENT TYPE OF STRUCTURAL SYSTEMS

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ABSTRACT

It is acceptable that construction industry is reaching to new bench marks by constructing certain Tall Buildings, includes of significant engineering. Construction of Tall buildings may be a complicated affair with the lateral loads playing a dominant role in design of the certain structures, where buildings need certain lateral load resisting structural system. With the evolution of technology numerous structural systems came out such as Shear Wall System, Tube in Tube, Core Out-trigger System etc. Considering the Building G+53 story's concrete Structure which is analyzed in ETABS V16.0.0 software package with different Earthquake Zones and using different Structural Systems such as Conventional System, Shear wall System, Core Out-trigger System and Wind forces exerted from IS-875-2015 (Gust Analysis), an attempt is made to compare the Performance of the three Structural Systems in all four earthquake zones Base shear, time period, top story displacement, story Drift, seismic weight of structure, and results are compared to arrive the foremost economical structure in a specific Earthquake Zone for a particular plan.

Key words: Reinforced Cement Concrete, Structural Systems, Response Spectrum Analysis, Wind Gust Analysis.

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1. INTRODUCTION

Reaching to top of the sky is setting the new benchmark for the Structural Engineering, numerous structures present within the world are taking the structure engineering to the new platform. let us take the instance of world tallest constructed building till date "Burj Khalifa-Dubai" A Mega Tall Structure, that has been constructed in 2010, the design of such Buildings will need Brobdingnagian engineering and new thinking. These sort of Structures are so sensitive to lateral loads so they're constructed with the lateral load resisting system. Selecting of such reasonably lateral load resisting system is likewise the primary a part of the whole project because the different structural system will have a tendency to differ the figure of the venture cost. Therefore using the optimum Structural System can give better resistance and additionally project cost can be reduced. There is not an absolute definition available for building to be called as a tall building, based on the height of building one can say that building is tall when the height of a building is less than 300m or 100 Story's, over that it is considered as a Super-Tall building. According to Indian terrain condition, it is divided into four seismic zones, 2, 3, 4 and 5 Zone respectively. While Zone 1 and Zone 2 were merged in Revision of IS 1893:2002[1]. Herein the fifth seismic zone is giving the very severe effect, while zone 2 is a mild one. For the dynamicity of the wind, clauses from the IS 875:2015(part 3)[2] is incorporated, wind gust analysis is used for dynamic effect of wind loads for preliminary design, while code suggest that for the better results one can go for the wind tunnel analysis, Since the natural frequency is less than one, the Dynamic analysis is to be done on the building. (Z. Bayati et.al , 2008)[3] Stated in Paper, that using the multi-level Out-trigger system the dimension of the member get reduced, as far the overturning moment at the base is reduced. They done the Case Study on the steel-framed office building of 80 story, Using ETABS, three sets four stories deep Out-trigger is compared, using both virtual and conventional Out-trigger system they found that, Conventional system having less lateral displacement at the top compared to virtual one but using of the virtual Out-triggers (Belt trusses and Basements as Out-triggers) provides benefits to the structure compare to the conventional system of Out-trigger. As difficult connections between Out-trigger are eliminated, also a differential shortening of the core and Out-trigger get avoided. (Vinay Sanjeevkumar Damam et.al , 2015)[4]Stated that the dimension of the shear wall depends on the load resisting capability of the shear wall that is if the dimension is more the force of attraction of the shear wall is more, and vice versa but as per code IS 1893:2002 even in New commentary, that the shear wall must be designed for the 75% of the total lateral loads while the column is only designed for the 25% of the lateral loads. (O. Esmaili et.al, 2008)[5]They made a study on a tall building of 56- stories, which is located at one of the dangerous faults, the tower is with shear wall system and it content with some irregular openings and giving a performance in gravity and lateral loads. To check the seismic performance of building a lot of non-linear analysis was done. They proofed that using a shear wall for both in bracing and gravity system is unacceptable, Main walls will carry both seismic and gravity loads. They also stated that Confinement of concrete in shear wall system is a good way to provide the ductility to the structure, By taking the time dependency into account in analyses, the critical demands for the structure would be found to occur at the middle height. The article published by (Krunal Z. Mistry et.al, 2015) [6], stated the optimum position of Out-trigger system H/2, H/4, 3H/4, which is similar as that S. Taranath's [7] .An analysis is done Using ETABS

V16.0.0 Evaluation Version with different types of Structural System that are Conventional System, Shear Wall system and Out-trigger System and results are compared. Many studies have been conducted to find out the efficiencies of these systems individually but a comparison of results of this kind all in one is the scope for this project in different earthquake zones.

1.1. General Considerations

1.1.1. Material Properties

Table 1 Material Properties

Section	Property
Column	M60
Beam	M60
Shear Wall	M60
Slab	M60
Rebar	HYSD 500 and HYSD 415 (for shear Stirrups)

1.1.2. Load Definition

Table 2 Gravity Load Definition

General		Wall Loads	
Dead Load	Weight of Structure	Wall	Brick Wall
Live Load	4 kN/m^2 (Ground to 52 Floor) and 1.5 kN/m^2 (53 floor alone)	Density	18 kN/m^3
Super Dead Load	2 kN/m^2	Load	6 kN/m(1-52 floor) and 3 kN/m (53 floor)

Table 3 Lateral Load Definition

Wind Loading		Seismic Loading	
Code	IS 875-2015	Soil Condition	Hard Soil
Analysis	Dynamic(Gust Factor)	Importance Factor	1
Category	1	Response Reduction Factor	5 (SMRF is considered)
Wind Speed	(Chennai) 50 m/s	Zone	2, 3, 4 and 5
K1, K3 and K4	1		
Interference Effects	Z2-1.25		

2. MODELING DETAILS

Slabs were modeled as a membrane, hence assumes that they will transfer all the loading to the secondary beams. Shear wall is modeled as the thin shell, and It is divided into grids. Sizes are chosen based on the Seismic Attraction of the forces IS 1893 (Part 1) [1] Clause 7.10.3. In secondary Beams, all the beams possess shear connections

Table 4 Mass Source Consideration

Load Type	Factors
Dead Load	1
Live Load	0.5 (>3 kN/m^2)
	0.25($\leq$3 kN/m^2)
Super Dead Load	1
Partition Wall	1

Due to Dynamicity involves in the structure and better participation of the modes, this condition will prefer to use of Ritz Vector instead of Eigen [8]. During the Modeling, the sizes of each member were fixed by trial and error. The Sizes were first randomly chosen according to the given literature then checked in ETABS v16.0.0, Hence if the sizes were failing then it was gradually increased or vice versa, likewise the sizes were fixed after a lot of iterations.

2.1. Structural System

During the project three structural system was taken in consideration, Conventional System, Shear Wall System and Out-trigger System.

2.1.1. Conventional System (CONS)

This is the structural System, without any lateral structural resisting system where the members are modeled in some huge dimensions.

Table 5 Property of elements in Conventional system

Section	Floor	Size	Section	Floor	Size
Primary Beams	GF to 15 16 to 30 31 to 53	450x1200 450x900 450x750	Column	Base to 7 8 to 20 21 to 35 36 to 45 46 to 53	2000x2000 1800x1800 1500x1500 1200x1200 1000x1000
Secondary Beams	GF to 15 16 to 30 31 to 53	450x900 450x750 450x600	Slab	GF to 15 16 to 30 31 to 53	220 200 180

**Sizes mentioned are in "mm"

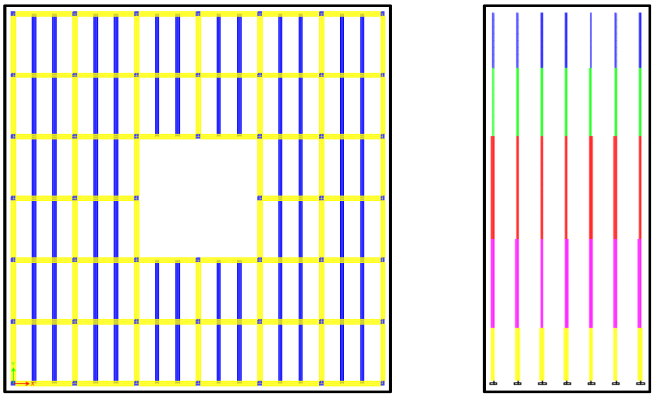

Figure 1 Plan & Elevation for Conventional System

2.1.2. Shear Wall System (SWS)

The center core is modeled as shown in the plan, as per the discussed literatures, behavior of the structure is better when the shear wall are provided in the center core and the L shaped at the corner of the building.

Table 6 Property of elements in Shear Wall system

Section	Floor	Size	Section	Floor	Size
Primary Beams	GF to 15 16 to 30 31 to 53	300x750 300x600 300x450	Column	Base to 7 8 to 20 21 to 35 36 to 45 46 to 53	1500x1500 1200x1200 1000x1000 800x800 600x600
Secondary Beams	GF to 15 16 to 30 31 to 53	300x600 300x500 300x400			
Slab	GF to 15 16 to 30 31 to 53	200 180 150	Shear Wall	1 to 7 8 to 15 16 to 33 34 to 53	750 600 450 300

**Sizes mentioned are in “mm”

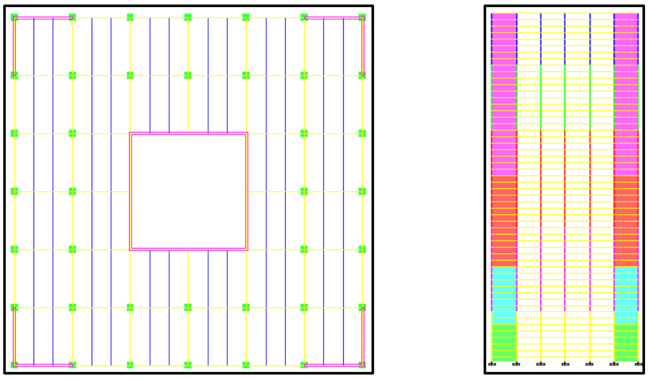

Figure 2 Plan & Elevation for Shear Wall System

2.1.3. Out-Trigger System (OTS)

The core is braced with the Bracing elements and the belt is adopted in the 14, 27, and 40 Floor. As per discussed journals and stated in the (Taranath, 2010)[7].

Table 7 Property of elements in Out-trigger system

Section	Floor	Size	Section	Floor	Size
Primary Beams	GF to 25 26 to 53	300x750 300x600	Slab	GF to 25 26 to 53	220 200
Secondary Beams	GF to 25 26 to 53	300x500 300x400	Centre Core Shear Wall	1 to 7 8 to 15 16 to 33 34 to 53	600 450 300 200
Column	Base to 7 8 to 20 21 to 35 36 to 45 46 to 53	1500x1500 1200x1200 1000x1000 800x800 600x600	Out-trigger Girder	14(H/4) 27(H/2) 40(3H/4)	1200x500 2400x1000 1500x3600

H-Total height of structure from ground level

**Sizes mentioned are in “mm”

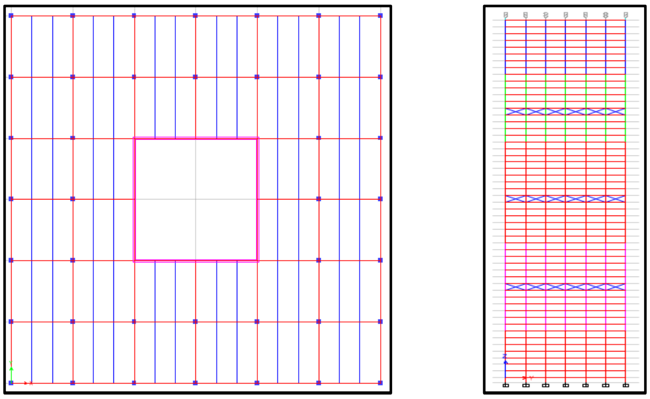

Figure 3 Plan & Elevation for Out-trigger System

3. RESULTS AND DISCUSSION

Conventional method is showing the high rate of displacement compare to other two system herein out-trigger system is showing the less displacement due to enough stiffness present at out-trigger story shows Conventional system is unable to perform in Seismic zone 5, this system showed the lateral displacement more than the allowable one i.e ratio of height of the building from base to 500. The conventional system showed a higher side of self-weight followed by a shear wall and Out-trigger System. Hence if Self-weight is more due to the higher sizes of members. As far No lateral resisting system columns and beams need to support all of the lateral forces through dimensions of the members were increased hence the self-weight is more. The out-trigger system having the less weight compare to the other two system because of that this system is considered as preferable one. Conventional system having more time period compare to the other two system, due to no lateral resisting system involved in this system shows that ductility is more in the conventional system, while the other two systems are rigid comparing to the conventional one. Base Shear is a highly dominating parameter for the lateral design of the structure, wherein base shear is showing more digits in seismic zone five due to an effect of liquefication while other three seismic zones are dominating by the wind loads. Story drift graph shows the sudden jerks pattern in the story, it indicates the location of the out-trigger system due to increment in the stiffness by keeping the lateral force same in the particular seismic zone, while other two curves show incremental values in drift throughout. In Conventional system due to an absence of any lateral resisting system, this system gives huge drift in stories. Here in chart values represent the data from the Seismic zone five as a pattern of the chart is same, while other three zones give the same pattern and values is less, there zone two represent lesser values followed by three, four and five.

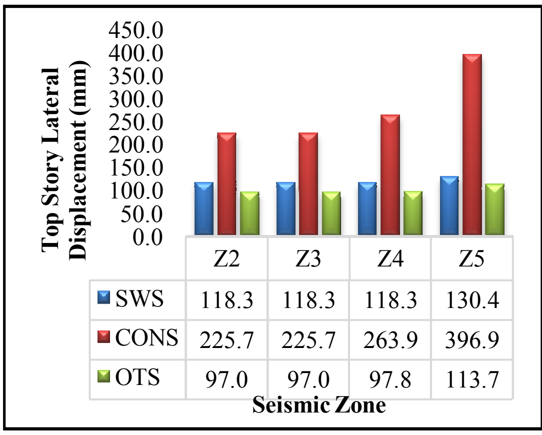

Figure 4 Top Story Displacement

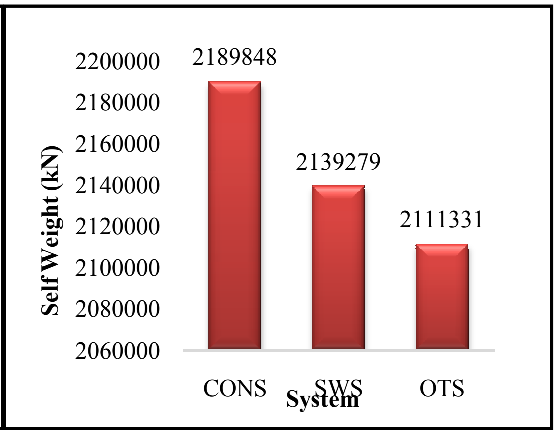

Figure 5 Self Weigh of Structure

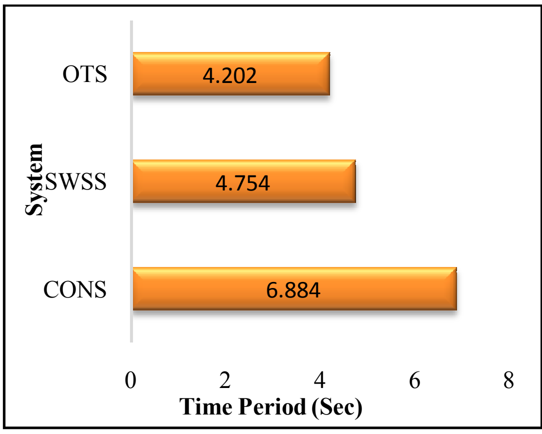

Figure 6 Time Period

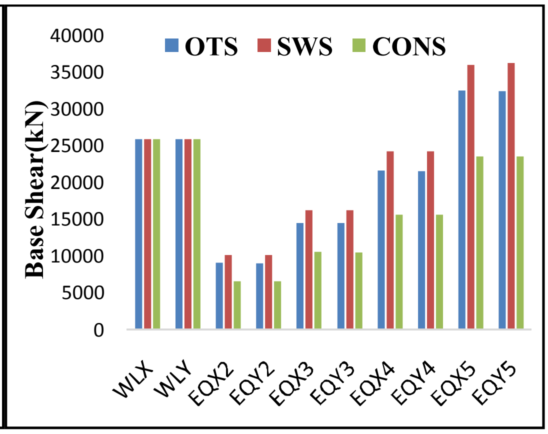

Figure 7 Base Shear

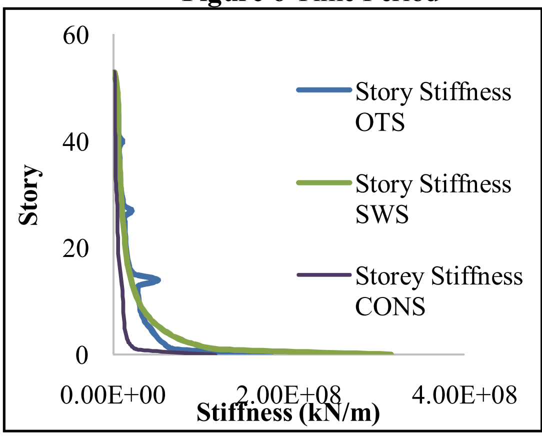

Figure 8 Story Stiffness

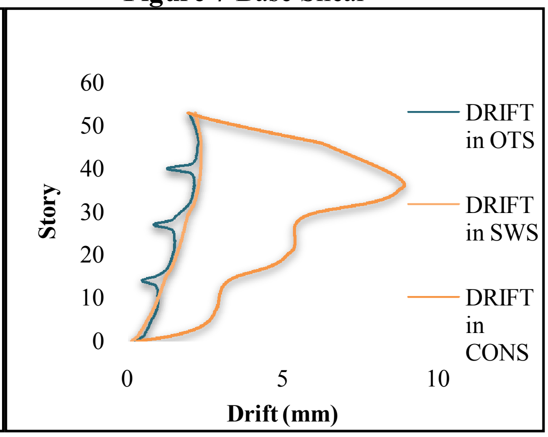

Figure 9 Story Drift

4. CONCLUSION

Since many authors have given their results related to structural systems, for the preliminary design the one can adopt the structural system based on few parameters, such as Seismic Zone, Wind loads, a height of the building, Plan dimension etc. While from all above one can preliminary fix the structural system. Herein Out-trigger system giving the tremendous performance with an adoption of huge engineering, while shear wall and conventional system turn to uneconomical one. Because of huge sizes involves of elements involves. Also, the performance of these two systems is not that much effective. As the height increases, lateral forces plays the dominating role, since till 300m, one can start the preliminary design by

adopting any of structure system such as out-trigger, shear wall etc., Beyond this height one can also go with a combination of the various structural system.

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